A METHOD FOR ENHANCING THE CAPACITY OF A CELLULAR RADIO-COMMUNICATION SYSTEM AND CORRESPONDING SYSTEM

The field of the present invention is that of cellular radio-communication systems and more particularly systems supporting multiple modulation schemes.

The capacity of the cellular radio-communication system can be defined as the average bit rate per sector, a sector being viewed as a communication channel in the radio communication system. In a cellular deployment, the capacity is directly related to the carrier to interference ratio value (C/I) achieved in the different sectors of the system.

For a given modulation scheme, the demodulator performance in term of bit error rate (BER) determines the operating point of the radio communication system. Depending on the channel coding, this BER performance can be greatly improved but this should be balanced with the loss of capacity due to the overhead of the channel coding.

In the following description, we refer to the usage of two modulation schemes having different modulation efficiency, for example 4QAM and 16QAM. The modulation efficiency corresponding to the number of coded bits per symbol. The invention can also be applied to any type of modulations having different modulation efficiency.

If the BER before channel decoding at a receiver of the cellular radio communication network is lower than a predefined threshold value, for example 10^{-4} , the use of an appropriate error correcting code, for example Reed-Solomon code, leads to a quasi error free channel after decoding. The BER lower than the predefined threshold value are obtained by ensuring different C/I values at the receiver depending on the

modulation scheme used. The necessary C/I values at the receiver to get a BER of 10^{-4} are assumed to be 12 dB for 4QAM and 19 dB for 16QAM. These values allow an implementation margin of 2dB. If we assume that the maximum output power is reached for 4QAM, we need a 2dB more back-off for 16QAM.

Parameters to calculate the C/I at the receiver side are the position of interfering distant users, the output power amplifier, the antenna gains , the signal bandwidth and the receiver noise figure. However, if in the up-link a power control is performed, the interference level and the C/I value at a receiving base station depends mainly on the position of interfering distant end-users.

The following description analyses the capacity enhancement in the up-link direction of a radio communication system, for example a cellular system using frequency reuse, deployed with several frequency channels using the same polarization. The invention can be extended to a radio communication system deployed with frequency channels using cross-polarization. The radio communication system is assumed to use link adaptation depending on the time varying link quality.

Figure 1 helps to analyze the interference level in a known cellular radio communication system using a rectangular cell pattern with 90° sectoring.

Figure 1 shows an ideal representation of a cellular system extending over an area covered by 5*5 bases stations located on a rectangular grid. The base stations are represented by heavy dots. A base station is situated in the middle of a rectangular cell divided in four 90° sectors each one supporting a different frequency channel. The different filling effects represent the different frequency channels used in the different sectors.

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Let call the lower left base station of figure 1, reference base station B1. The upper right sector of the reference base station B1, called reference sector S1, uses a frequency channel represented by discontinuous lines bent to the right side of figure 1.

In the uplink, a end-user located in a given sector transmits its signal toward the base station belonging to this sector with a predefined directivity depending on the antenna of the end-user.

Possible interference in the reference sector S1 only come from end users located in distant sectors using the same frequency channel as reference sector S1. If the antenna directivity is assumed to be very narrow, only distant end-users aligned with their corresponding base station and with the reference base station B1 generate interference in the reference sector S1. With the cell pattern described in figure 1, interfering end-users located along bold portions of lines L1, ..., L8 in sectors of distant base stations using the same frequency channel as reference sector S1 generate interference at the reference base station B1.

The level of interference depends on the distance between the interfering end-users and the reference base station B1. Three locations along bold portions of line L1, L2, L3 give a C/I up to 14 dB if interfering end-users are located on them. Five more locations represented by bold portions of line L4, ..., L8 give a C/I of 19 dB and seven locations not represented on figure 1 an interference level of 22dB below the carrier level. Depending on the traffic at these locations, the end-users located in the reference sector S1 are affected by these interfering end-users.

In prior art solutions, the worst case is considered to determine the interference level to be taken into account for the whole sector. In that case a C/I of 14dB is the worst case. To ensure a BER of 10^{-4} before decoding

the use of a 4QAM in the sector can be appropriate. The disadvantage of this worst case is that it is sub optimal.

As the interference level can vary quickly depending on the traffic along the bold lines L1, ..., L8 in the sectors using the same frequency channel as the reference sector S1, a possible solution to enhance the radio-communication system capacity would consist in adapting the link capacity to interference level in real time.

This solution could be achieved by the use of adaptive antennas. This kind of product is, however, not yet available and seems not to be available soon for the millimetric frequency range.

A particular object of the present invention is to provide a method for enhancing the capacity of a cellular radio communication system with reduced needs of real-time requirements.

This object,. and other that appear below, are achieved by a method of enhancing the capacity of a cellular radio-communication system, each cell of which comprising a base station and end-users able to communicate with the base station by using a first modulation type over a first communication channel. Any cell experiences an interference level from distant end-users communicating with their corresponding distant base station by using the same first communication channel. According to the method of the invention, the end-users located in at least one domain of the cell in which the interference level is lower than a predefined interference level communicate with the base station by using a second modulation type over a second communication channel, where the second modulation type has a higher efficiency than said first modulation type. The size and location

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of the domains depend on the antenna directivity of the end-users and on the relative positions of the distant base stations and the base station.

An advantage of the present invention is to enhance the capacity of a cellular network with low costs.

The present invention also concerns a cellular system according to claim 6.

Other characteristics and advantages of the invention will appear on reading the following description of a preferred implementation given by way of non limiting illustration, and from the accompanying drawings in which:

Figure 1 is a known cellular radio communication system using a rectangular cell pattern with 90° sectoring;

Figure 2 shows a cell of the cellular system as showed in figure 1 supporting two modulations types on two communication channels according to the present invention;

Figure 3 shows a cell of the cellular system as showed in figure 1 supporting two modulations types on four communication channels according to the present invention.

As already described above, the bold portions of lines, L1, ..., L8 represented in figure 1 are situated on five directions which are source of interference and incompatible with the use of a higher efficiency modulation. On the contrary other directions are affected by very low interference and are compatible with the use of a higher efficiency modulation. The five above mentioned directions in reference sector S1, and an area around these directions (to take into account the non negligible antenna directivity; a possible antenna directivity is 6°), are preferably assigned to a dedicated first communication sub-channel used.

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The modulation used on this first sub-channel is 4QAM. The other regions are preferably assigned to a second sub channel different from the first sub-channel. The modulation used on this second sub-channel is preferably 16 QAM.

With an antenna directivity of 6° (worst case) at the end-user side, the portions of the sector S1 not suitable for the use of 16QAM, i.e. experiencing a C/I lower than 19dB have been calculated. This is shown in figure 2. Figure 2 represents the reference sector S1 of figure 1.

The users located in the five sub-areas SA1, ..., SA5 use the first communication sub-channel with 4QAM modulation and the end-users located in the rest of the sector use the second communication sub-channel with the 16QAM modulation. Preferably, the communication sub-channels used in the reference sector S1 as shown in figure 1 correspond each one to the half of the bandwidth allocated in prior art system to a sector.

The total area where a 16QAM modulation can be used represents 54% of the cell area, the other 46% corresponding to a area where the 4 QAM modulation has to be used. If the users are uniformly distributed in the cell, the capacity enhancement is equal to 1x0.54+2x0.46=1.46 compared to the 4 QAM capacity being taken as unit. The rain effect has little influence on the value of this coefficient.

In another embodiment of the invention, the original frequency channel is divided in four sub-channels having each one 1/4 of the bandwidth of the whole bandwidth allocated in prior art systems to a sector. The reference sector S1 is divided in four types of regions.

Figure 3 represents the reference sector S1, the two types of striped areas are the areas where an end-user can experience a high level of interference from other distant sectors. The end-users inside these striped areas are then assigned to 2 specific sub-channels using a 4 QAM

modulation scheme. The two type of punctured areas are the areas where a end-user can experience smallest level of interference from other distant sectors. These punctured areas can then use the further two communication sub-channels with a 16 QAM modulation scheme.

As showed in the above description, the present invention provides a method to enhance the capacity in the up-link of a cellular radio communication network by assigning some parts of the sectors to dedicated sub-channels and using both 4QAM and16 QAM modulations.

The invention also apply to any cellular radio communication network having any topology provided the location of the base station and the sectors of the cell are known.

The cellular radio communication system according to the invention comprises preferably fixed end-users communicating over a radio link with their corresponding base station. The use of the modulation depending only on the location of the fixed end-user. The end-user may then only support the modulation type used in the domain where it is located.

In another embodiment of the invention, the cellular radio communication system comprises mobile end-users which can move from one domain using a first modulation to another domain using a second modulation. In that case, the system should also support means for having the terminal switch from an first modulation type to another modulation type according to the place where it is currently moving to. This may be achieved by using a positioning system, as for example GPS, to follow the moves of the end-users and couple the results of the positioning system with a signaling mechanism to communicate to the end-user if it has to change the used modulation type. The base station in with the end-user is currently

located or the base station in association with the mobile switching center may be responsible for this procedure.

The idea of the invention can also be applied to the down link direction of a cellular radio communication network.

The idea of using sub-channeling an allocated bandwidth can be understood as described in the preferred embodiment of the invention as a frequency sub-channeling where the allocated bandwidth is divided in different frequency sub-channels. Another possibility can be a time sub-channeling where the allocated bandwidth is divided in several time sub-channels or a code sub-channeling where the allocated bandwidth is divided in several code sub-channels.

The invention should not be restricted to the use of two different modulations having different efficiency. More than two modulations having different modulation efficiencies may be envisaged.

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